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MEASUREMENT OF VISUAL REACTION TIME IN BOTH POSITIVE AND TRANSVERSE G

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MEASUREMENT OF VISUAL REACTION TIME IN BOTH POSITIVE AND TRANSVERSE G

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ABSTRACT. Different subjects were tested for their visual reaction time while under centrifugal force. When this force was in a chest to back direction then at 4G there was a slight increase in reaction time and scatter. At 8G the reaction time was definitely prolonged and the scatter noticeably increased. When the centrifugal force was in a head to buttocks direction then an increased reaction time and scatter took place at 3G, while at 4.5G it led to omitting reactions.

During experiments with the centrifuge at the Aviation-Medical Research Institute of the State Aviation Ministry in Berlin, subjects exposed to high centrifugal force at times showed little interest in their surroundings and appeared restricted in their natural reaction to outside stimuli. The subjects were so slow and often reacted in such a way that one had the impression they had lost control of their actions. L. Buhrlen writes about this as follows: "The rate of reaction and mode of thinking appeared to have been disturbed, since the bell signal had to be prolonged far beyond the required duration. Upon later questioning it was explained that the subject clearly heard the experimenter call out the reduction of centrifugal force (consequently feeling relief) at the same time that the signal bell was sounded. The related thought conclusion, however, to stop the ringing by thumb pressure, was only drawn after a prolonged period." In the films of H. v. Diringshofen and recently those of Ruff, the subjects usually show an apathetic facial expression after stopping the acceleration. Since in modern high speed aircraft the human organism is subjected to high centrifugal forces in curvilinear flight just when increased attention and quick action are required, it is of interest to /277*

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*Numbers in the margin indicate pagination in the foreign text.

determine how reaction time is altered during this period. Fractions of a second may be of great significance here, as the following consideration shows: an aircraft flies at 600 km/hour, that is 165 m per second, or 34 m/0.2 seconds, the average reaction time. If this reaction time were to increase under the effect of centrifugal force, there could be serious consequences in certain circumstances. For this reason experiments were conducted on the centrifuge to determine how human reaction time changes when subjected to high centrifugal forces.

First, a few introductory remarks. According to Wirth, a reaction trial means an experiment in which the subject has to respond immediately with the movement of voluntary muscles after a certain stimulus. The time between the start of the stimulus and the movement is the reaction time. This is possible to record since it is limited by two physical processes, which are distinct from the psychological processes. Various conditions must be fulfilled if the most generally valid results are to be achieved by this method. The shortest possible times must be reached. It is first necessary to compensate for the self-observation, since this consumes energy and with it time. Furthermore, the tendency to react to the signal before it begins must be avoided as much as /278
possible, since this can occur with both experienced and inexperienced subjects and leads to the so-called reaction error. These conditions are best met by maximum practice.

We tried to comply as much as possible with these conditions for our trials, but we are aware that in spite of it the times we found do not represent absolute values. The tests on the centrifuge constitute a difficult physical and psychological strain even for experienced subjects. The values we found are therefore not to be compared with those found under the most favorable conditions. For these reasons we had to be satisfied with "simple" reactions. A known sense stimulus of medium intensity, which stood out at once from the previous surroundings, had to be answered with a wholly familiar, easy movement. Also, for our tests we did not deal with the three main components of the reaction: the motor, the sensory, and the apperceptive. Although these play a part in the absolute measurement of minimum time, they have no worthwhile significance for comparative tests. It is to be assumed that during the tests the subject reacted with extreme muscular control, since only the recognition of specific stimulus motive (disjunctive reaction) requires extreme sensory control, while we measured only simple reaction times.

The tests were made on the centrifuge of the Aeronautical Medical Research Institute of the State Aviation Ministry. The usefulness of the centrifuge tests for the basic understanding of the effect of speed has been proven since the work of Ranke and co-workers and Ruff. With careful critique it is possible to translate the results to conditions in flight. The details of construction of the centrifuge are shown in the work of L. Bührlen and S. Ruff. The number of Gs was used as the measure of the centrifugal force effect.

Method

In order to measure the visual reaction time, the subjects were instructed to pull an iron rod control stick (St) as fast as possible after a given light signal (SL) (Figure 1). In order to have the conditions as uniform as possible for all the subjects, we constructed a contact disc (MU) of 15 cm diameter on which 10 contacts were mounted at irregular spacing. An electric motor moved the disc at a constant speed. The contacts closed an electrical circuit, which caused a small, white 4 volt bulb to light up in the centrifuge at intervals corresponding to the spacing of the contact pins (average deviation 0.2%). This light signal served as stimulus to the subject who otherwise sat in complete darkness. The small bulb was positioned below the height of the subject's eyes, at about 1 m distance, so that it could be seen without effort. The disc made one revolution in 18 seconds, so that 10 stimuli were sent out in this time. It was found that one could react well to this series of stimuli. If the series of stimuli were slower, the subjects would have been exposed to the /279 action of the centrifugal force for altogether too long, and to the consequently greater stress. The width of the contact pins was chosen so that the bulb was lit for 0.05 second at a revolving time of 18 sec.

In order to be able to record the series of stimuli and the reactions of the subjects, a magnet (M) was installed on the centrifuge parallel to the lamp in the same circuit, which at the moment the contact disc closed the contact, that is at the same time the signal lamp was lighted, it pulled a flat spring

(An). A small mirror (Sp) was attached on the forward end of this spring which received a ray of light from a line thread lamp and reflected it into the slit of a cymograph attached to the centrifuge. In this way it was possible to record each movement of the spring on a film on which the exact time was also recorded by means of a point light source and Jaquet clock on each centrifuge revolution.

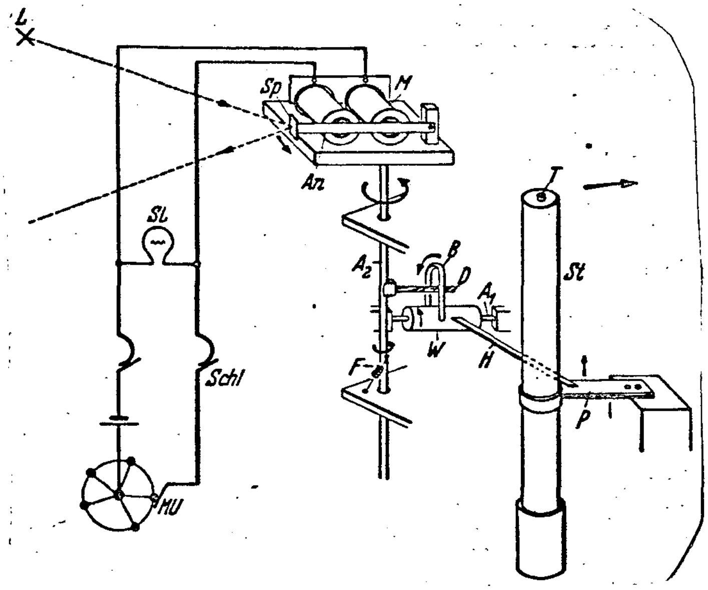

Figure 1. Test Arrangement for Recording the Visual Reaction Time. Description in the Text.

The magnet was fastened to the top of a vertical rotatable iron rod (A_2), which was held in a steady position by a small spiral spring (F). The iron rod was connected with the bolt (D) led through the bracket (B), the revolving drum (W) over the arbor (A_1) and the lever (H) connected to the control stick to be activated by the subject, so that movements could be transferred to it, when the subject pulled on the control stick, which was fastened with a strong flat spring (P) and stood in such a way between the knees of the subject that it could be grasped with both hands. This movement was reproduced as a small turn to the left. Now, since the above described magnet was fastened to the top of the rod, it moved with each movement of the control stick; the small mirror attached to the flat spring moved with it. We ensured that the magnet did not produce any kind of noise, since only the visual and not the acoustical reaction time was to be measured. The acoustical disturbance was eliminated by /280
appropriate rubber cushioning.

All movements of the small mirror were recorded on the film (Figure 2). At a rest position a straight continuous line was drawn. When the circuit was closed, i.e., when the signal lamp was lighted, the magnet attracted the flat spring. In this way the continuous line on the film was interrupted and gave the precise starting time of the stimulus. A short time later, depending on the reaction time of the particular subject, the mirror was again moved through the deflection of the control stick, but this time in the opposite direction. In this way the line on the film was interrupted a second time, and thereby indicated the moment when the subject moved the control stick. The distance between these two interruptions gave the reaction time. The films that were thus obtained were precisely evaluated by means of a magnifying glass to 1/200 mm. The length of the reaction time could be determined from the continuously measured time divisions on the upper edge of the impulse and the beginning of the reaction. Ten consecutive reaction times were taken and from there we calculated the average value. The scatter was determined by the difference of the average value according to the method of least squares.

The reaction time was investigated for 9 subjects in 17 tests under centrifugal force. In order to obtain the least possible scatter, practice runs by the subject were made first. These always took place under the same conditions with the resting centrifuge in a completely dark room. Of course, during these practice runs, as well as later during acceleration, there was always the greatest possible silence so that the subject would not be distracted by outside influences, and in order to eliminate any erroneous reactions. The duration of the trial runs was 15-30 minutes in the daytime. They were always held at the same time of day, between 1 and 3 o'clock, since it was shown that the acceleration could be best endured shortly after eating. After the subjects were trained for 5-6 days, a trial film was made at rest to show how the particular person reacted. /281

For most subjects this practice time was enough to completely eliminate erroneous reactions and to reduce scatter to a minimum. We consciously avoided directing the subject's attention in either a sensory or motor direction. When the best film showed that erroneous reactions no longer occurred and that the scatter was as slight and constant as possible, the subject was exposed to the acceleration. Before each acceleration experiment, the practice was held once more, but only for one minute, in order not to tire the subject; this was followed by a short rest. Then the subject had to react through the whole trial.

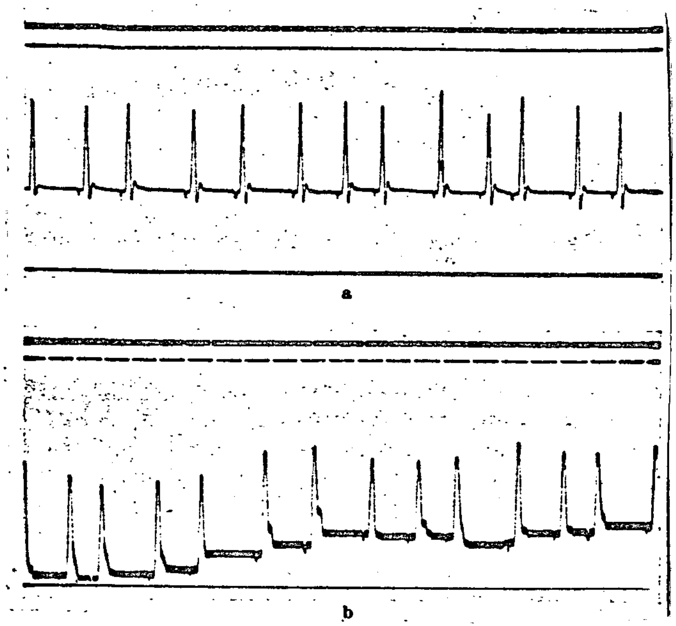

Figure 2. Recording of the Reaction Time a, at rest; b, under acceleration. From the top to the bottom, time mark (1 sec.), revolutions of the centrifuge, recording of the reaction time. Downward turn, signal; upward turn, reaction.

Results

Since the position of the subject in relation to the centrifugal force is of fundamental importance, the reaction time was investigated in the chest-back direction as well as the head-buttocks direction. In the first case 10G can be endured without any serious distrubances, while in the second case, considerable visual disturbances occur at 4.5G. Trials were therefore carried out in both positions.

First, tests were made in a recumbent position (direction of centrifugal force chest-back). Portions of the experiment were carried out in this position for 30 sec before each action of centrifugal force. The centrifuge was then set into motion and accelerated to 4G. When this was reached after 45 sec, another recording of 30 sec duration was made, whereupon the centrifuge was stopped. As soon as it stopped, after a total duration of 120 sec, it was then again recorded for 30 sec The subjects reacted through this whole period, which is absolutely possible in this position and for this action of centrifugal force. We thus obtained 3 film sections of 30 seconds each for each experiment. These trials up to 4G were followed by those up to 8G; they were carried out in the same way and with the same subject. This, however, was considerably more difficult, since we also wanted to record a 30 sec portion at the 8G level, in parallel to the tests up to 4G. Exposure to a 30 sec long acceleration at 8G means after all a rather severe stress on the organism and requires the fullest initiative on the part of the subject. In spite of this, we could measure the reaction time of five subjects even under this increased centrifugal force (Table 1).

TABLE 1.

R.13	Subject	At Rest		4 g		8 g		Afterward	
		Reaction Time	Scatter	Reaction Time	Scatter	Reaction Time	Scatter	Reaction Time	Scatter
V.14.2	Bu.	0.245	0.022	0.242	0.025			0.282	0.024
V.14.3		0.221	0.026			0.282	0.030	0.228	0.025
V.20.2	Ha.	0.216	0.014	0.269	0.037			0.241	0.031
V.20.3		0.212	0.015			0.262	0.048	0.240	0.025
V.21.1	Ko.	0.238	0.017	0.312	0.052			0.264	0.019
V.21.3		0.225	0.025			0.395	0.119	0.244	0.026
V.22.2	B	0.212	0.014	0.238	0.036			0.222	0.019
V.22.3		0.223	0.029			0.297	0.076	0.254	0.036
V.17.2	La.	0.235	0.011	0.264	0.030			0.273	0.018
V.15.3	Pl.	0.273	0.016			0.252	0.029	0.227	0.029
Average		0.226	0.019	0.265	0.036	0.298	0.060	0.244	0.025

The table shows the values from 10 consecutive reactions at rest, at 4G, /282 at 8G, and after stopping the centrifuge. We see from this that at a level of 4G there was just a perceptible increase in the reaction time for all subjects. Besides this, the scatter becomes somewhat greater than at rest. It was to be expected after these individual results that well-defined increases of reaction time would occur at still higher centrifugal force. Actually, a clear increase could be shown at 8G for all subjects, as is also seen from Table 1. This deterioration of the reactions is shown even more clearly by the scatter, which is particularly important in practice. The reading of subject Ko. was noticeably poor. We have not been able to decide up to now whether constitutional factors play a part in this.

Various factors can be assumed for the deterioration of the reaction time in this position. First of all, a psychological effect is quite generally significant, as is true for every centrifuge trial. There are also acoustic stimuli during the ride in the centrifuge, brought about by the slip stream and the noise of the centrifuge itself, which surely affect the concentration during the actual trial in contrast to the condition at rest. A third factor may be mentioned, the difficulty of breathing which can be considered as the most significant factor in the prolongation of the reaction time. All subjects stated that the breathing difficulty was most uncomfortable and that the feeling of choking connected with it greatly affected the concentration. No disturbance in vision was ever indicated in this position.

This was followed by trials in the head-buttocks centrifugal force direction which corresponds to the position during curvilinear flight, carried out in a similar manner, only with the difference that at 3G all reactions of take--off were recorded as well as the whole course of the trial at 4.5G, and the centrifuge was stopped immediately after reaching a certain G-value. We thus avoided exposing the subjects unnecessarily long to high centrifugal forces, which are poorly tolerated in this position. The centrifugal forces up to 3G were well tolerated by all subjects. For the additional trials to higher G values, the subjects were instructed to react until disturbances occurred. These occurred at 4.5G and expressed themselves in visual disturbances and intolerable leg pains, so that the subject could no longer carry out the assigned task. The head on the Totmann bell (M) was then released, which was the sign to apply the brakes. During the take-off, the reactions started again as soon as possible and were recorded continuously up to the end. Unfortunately, it was not possible to use the same subjects for these trials, as for the first series of tests. First of all it was generally quite conspicuous that in spite of zealous practice by the subjects, the values at rest in this position were somewhat prolonged (Table 2). This may be explained by the unnatural position, since according to Wirth the position of the subject is of considerable influence on the reaction time. ("The more unaccustomed and strained the posture becomes on the whole and in the reactions to be carried out, the longer will the minimum time be exceeded.") /283

An average value of 0.265 sec. was obtained. The individual values may be seen in Table 2. The average values, each calculated from 20 reactions, are given in the columns of starting and take-off. The other columns show average values from 10 reactions. From these it turns out that the reaction is clearly

prolonged at 3G for all subjects, and that scatter varies there considerably. This is shown particularly well for subject Schw. At a centrifugal force of 4.5G there is again an increase over the values found at 3G. To this may be added that a part of the reactions were omitted because of the disturbances experienced by subjects Ste. and Schw. shortly after ringing, as the centrifuge was decelerating. Ste. did not react 4 times and Schw. 10 times. Only /284
at 2G did the reactions start again for these two subjects. On the whole, the effect of centrifugal force was tolerated variably. This is also shown by the values in the centrifuge after the acceleration. Thus, subject Schw. had a considerable increase in the reaction time after the test, compared to the values at rest before, while the values for subject Pl., after stopping the centrifuge, immediately returned to the starting values.

The disturbance to the blood circulation in the brain may well be the main reason for the increase in reaction time, which becomes plainly evident even at 3G and increases at greater centrifugal force, until a recording of the visual reaction time becomes totally impossible because of the blackout due to the same reason.

Summary

The variation of visual reaction time under the action of centrifugal force was investigated on the centrifuge for 8 different subjects in 17 trials.

When the centrifugal forces act in the chest-back direction, then at 4G 5 persons experienced a slight increase in reaction time and a slight increase in scatter. At 8G the reaction time was definitely prolonged and the scatter increased noticeably.

When the centrifugal forces act in the head-buttocks direction then even at 3G there is an incontestable increase in reaction time and scatter. At 4.5 G these changes are even more marked and the visual disturbances that appear lead in part to omission of reactions.

TABLE 2.

R.13	Subject	At Rest		Starting		Maximum Acceleration				Take-off		Afterward		
						3g		4.5g						
		Reaction Time	Scatter	Reaction Time	Scatter	Reaction Time	Scatter	Reaction Time	Scatter	Reaction Time	Scatter	Reaction Time	Scatter	
V.29.3	Ste.	0.258	0.042			0.328	0.092			0.312	0.048	0.273	0.036	Stopped at 4.7G because of disturbances. Loss of 3 reactions during the acceleration
V.29.5				0.272	0.035			0.298	0.041	0.306	0.045	0.232	0.008	
V.32.2	Schw.	0.244	0.040			0.391	0.089			0.332	0.074	0.332	0.073	Stopped at 4.5G due to disturbances and severe leg pains
V.32.3		0.281	0.024	0.378	0.082			0.368	0.115	0.340	0.097	0.345	0.103	
V.34.2	Pl.	0.275	0.023			0.308	0.032			0.291	0.032	0.266	0.021	Stopped at 4.6G due to slight visual disturbances
V.34.3		0.286	0.042	0.298	0.038			0.322	0.039	0.308	0.031	0.254	0.105	
Average		0.265	0.029	0.316	0.055	0.334	0.063	0.329	0.068	0.306	0.053	0.279	0.040	

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